ancestry of some later echinoderm, must be a descendant of an ancestor which had the potential to give rise to both stalked and free-living types. Inasmuch as representatives of both conditions are present in the Lower Cambrian and are already differentiated, they must have arisen and diverged a considerable time before the beginning of the Cambrian. The free-living character of the new form suggests that the common ancestor may not have been a stemmed (or pelmatozoic) echinoderm. Of all classes hitherto known, the edrioasteroids would seem to be closest to the helicoplacoids and may well be closely related to them.

The new class Helicoplacoidea may be diagnosed as follows:

Free living, fusiform placoid echinoderms with spirally pleated, expansible test; apical and oral poles at opposite extremities; columns of plates arranged in a spiral; ambulacra and "interambulacra" present; new "interambulacral" plates originating at apical pole and becoming more oral in position as subsequent plates are added (origin of ambulacral plates obscure). Lower Cambrian, California.

The "interambulacral" areas are formed of three columns of plates. In the retracted slate (Fig. 1 *B*) the central column is external and the two lateral columns folded internally; to expand (Fig. 1*A*) the lateral columns fold out laterally and floor the "valleys" adjacent to the ridge-like medial column. The three columns of an area appear to originate from a single center. In the species here described there are 10 "interambulacral" areas. The principal ambulacrum makes at least two full spiral turns, starting at the mouth, but does not reach to the apical pole. The secondary ambulacrum first appears about 180° along the spiral from the mouth and then continues for approximately another 180°, being separated from the first by two "interambulacral" areas throughout most of its length. In one specimen (Fig. 1*E*) the two ambulacra clearly join, apparently adapically and the principal ambulacrum continues. In the retracted state the medial "interambulacral" column imbricates adapically posterior to the branching of the ambulacrum, and slightly adorally anterior to this point. The ambulacra are composed of several rows of small plates. As yet no podial pores nor anal and genital orifices have been recognized. The structure of the peristome is uncertain but the mouth apparently was not more than 1 mm in diameter. Grossly, the symmetry of the test at least as far as the interambulacra are concerned, should be considered as radial, modified by torsion to spiral.

The new genus *Helicoplacus* consists of helicoplacoid echinoderms, in which the primary ambulacrum has a single branch. From Greek *helix,* a spiral, and *plakos,* a flat plate. Type species:

Helicoplacus gilberti, n. sp. (*5*). "Interambulacra" with about four turns; plates of medial column slightly longer than those of lateral columns; rounded external edges of medial plates with fine longitudinal ribs, and intermittently developed nonarticulated spines adorally (on every fourth to ninth plate); spines not present medially or adapically on test; adult specimens about 35 mm long.

Helicoplacus curtisi, n. sp. (*6*). Similar to *H. gilberti* but plates of medial "interambulacral" columns without longitudinal ribs and with outer edge sharply angled; large, elongated, nonarticulated spines locally present medially on test; spines becoming reduced adapically but adapical margin of plates with an angle suggesting incipient spines; "incipient spines" may be present on adjacent plates near apical pole; adult specimens larger than *H. gilberti*, possibly attaining a length of about 75 mm.

Helicoplacus curtisi (Fig. 1, *C, D*) may be distinguished from *H. gilberti* (Fig. 1, *A, B, E, F*) by the nonribbed, prominently spinose plates on the medial portion of the test. In the type specimen the ambulacrum either has more columns of plates than in *H. gilberti* or else it is expanded so as to show columns that are hidden in the type of that species.

There may well be signal phylogenetic implications in these new-found organisms, even though it has been said that "the original echinoderm must have been very different from those that we know today and that we can scarcely hope to unravel the history of the phylum" (*7*).

Inasmuch as the Helicoplacoidea and the contemporary eocrinoid *Eocystites* (on which Caster is currently working) are the most ancient echinoderms yet discovered, are both free-living, and yet are morphologically widely separated from one another, it is apparent that considerable doubt is cast upon the generally accepted view (*8*) that the ancestral echinoderm was attached. Need for a reconsideration of all subphyla of the Echinodermata hitherto proposed is also indicated.

J. W. DURHAM
University of California, Berkeley
K. E. CASTER
University of Cincinnati,
Cincinnati, Ohio

References and Notes

1. C. A. Nelson, *Bull. Geol. Soc. Am.* **73**, 142 (1962).
2. University of California Museum Paleontology Invertebrate Collection Localities B-4028, B-9852, and B-9853.
3. C. A. Nelson, personal communication, 11 Dec. 1962.
4. As defined by H. B. Fell, *Tuatera* **10**, 138 (1962).
5. Holotype No. 37847, paratypes 37848-37854, University of California Museum Paleontology (Berkeley). Named in honor of C. M. Gilbert.
6. Holotype No. 37844, paratypes 37845, 37846, University of California Museum Paleontology (Berkeley). Named in honor of G. H. Curtis.
7. L. H. Hyman, *The Invertebrates, Echinodermata* (McGraw-Hill, New York, 1955), p. 696.
8. See for example, L. H. Hyman, *ibid.*, p. 697; David Nichols, *Echinoderms* (Hutchinson, London, 1962), pp. 20, 176–178.

15 February 1963

Methodological Questions in the Study of One-Trial Learning

Abstract. *The substitution method may lead to poorer learning than the customary repetition method when learned pairs are eliminated after each trial. This results from a procedure in which the subject is required to spell the response. Spelling leads to greater difficulty in learning the response item but repetition tends to counteract it.*

Recent experiments have led to the conclusion that, in the learning process, associations are formed either completely or not at all in one trial (*1*). The number of trials to criterion is the same when missed pairs are replaced by new ones after each trial as it is when the same pairs are presented on every trial. Although these results have been confirmed when the same procedure is followed (*2*), certain variations have led to different results (*3, 4, 5*). One such variation arose from a possible difference in interference between learned and unlearned pairs and learned and new pairs (*6*). Kristofferson tried to eliminate this possible flaw by discarding correct items after each trial for both groups instead of retaining them. Although this is an adequate test of the all-or-none hypothesis it was not used in the original experiment; by discarding correct items after every trial, the list becomes increasingly short. This may change the nature of the task for the subject. Toward the end the list will contain only a few items which perhaps can be retained in immediate memory.

Although Kristofferson did indeed obtain contrary results (the groups seeing the same pairs took less trials to learn than groups seeing new pairs in place of those missed) he had also introduced another change in procedure. Instead of having the subjects pronounce the second member of each pair of items in the test, as in the original experiment, Kristofferson in two experiments had them spell it. In his first experiment no recitation was required during learning; in his second experiment the subject pronounced the first word and spelled the second (*7*). In this respect, his findings conform to those of certain other experiments where the substitution procedure was used. Spelling leads to a different result from that obtained in experiments where the pronouncing method was used (*3, 4*).

We have repeated Kristofferson's procedure of dropping out the correct pairs after every trial for both groups in order to see whether it was this change or the change from pronouncing to spelling which led to the different results. In experiment 1*A*, the subjects of the control group had those items presented on each trial which were missed on the preceding trial; for the experimental group, each subject on any given trial was given new items equal in number to those missed on the previous trial. All subjects pronounced each pair as it was presented during the learning trial and pronounced the response member on presentation of the stimulus during recall. The same "dropping out" procedure was used for the two groups of experiment 1*B*, except all subjects had to spell out the response member on every learning and recall trial.

Items consisted of consonant-vowel-consonant nonsense syllables of 47 to 53 percent Glaze association value. The 160 syllables chosen were randomly paired, giving a total of 80 pairs. These were presented to subjects on cards (3 by 5 inches). The stimulus item alone on the reverse side of the card served as the test item. The cards were shuffled and separated into 10 series of eight each. For experimental subjects the new substituted pairs were drawn from a different one of these series on each trial. The pairs of one of these series were presented to the control subjects. The time intervals were those of the original experiment as were the instructions except for those related to spelling in experiment 1*B*.

In experiment, 1*A*, (pronouncing) 30 subjects were assigned to each of the two groups. For the two groups of 30 each, learning in the first trial was approximately equal although it was slightly better for the control subjects (mean of 1.0 compared with a mean of .77). In experiment 1*B* (spelling) there were 15 subjects in each condition. For these two groups, learning on the first trial was identical.

The mean number of trials required to complete the task in experiment 1*A* (pronouncing) was 5.5 (S.D., 1.2) for the control group and 5.8 (S.D., 1.6) for the experimental group. The mean number of errors was 20.6 (S.D., 8.8) and 22.6 (S.D., 9.9) respectively. Neither of these differences is statistically significant. In experiment 1*B* (spelling), the mean number of trials for the control group was 6.00 (S.D., 1.76), whereas it was 8.60 (S.D., 1.18) for the experimental group (including two subjects who took more than ten trials and were scored as 10). The mean number of errors was 24 (S.D. = 7.6) and 35.5 (S.D. = 11.9), respectively. Both of these differences are significant since $p < .01$.

From an analysis of the nature of the errors the proportion of no-response errors to total errors was greater for the experimental groups than for the control groups, while the proportion of intrusion errors was smaller for the experimental groups than for the control groups. Thus, the experimental subjects were somewhat less inclined than the control subjects to emit any response when they felt they did not know the answer. In absolute terms the difference in performance between the two groups of experiment 1*B* is accounted for more by no-response errors than by intrusion errors. Interestingly enough, the latter difference is due exclusively to cases where only two of the three letters are correct. These results show that the spelling-out procedure makes the learning of a list of paired associates more difficult for the subjects who see new pairs on every trial. Thus, Kristofferson's results can be accounted for, not in terms of the elimination of the interference he claimed was present in the original experiment, but rather in terms of the use of the spelling-out method which he introduced. In passing, it is worth noting that the pronouncing procedure does achieve control over the subjects' responses during training and still fails to yield a difference between control and experimental groups (*8*).

At this point, we shifted our attention to the question of why "spelling out" results in so great a difference in learning for the experimental subjects. The control groups did not differ significantly in mean trials to learn in both experiments. Apparently the spelling-out method does not lead to poorer learning when the items are repeated from trial to trial as is the case for the control condition. An examination of performance on the first trial for the subjects in all experiments (including experiment 2 described below) reveals a superiority for the pronouncing condition. Similarly a comparison, trial by trial, of the two experimental groups (1*A* and 1*B*) shows a superiority for the pronouncing condition. Thus wherever there is no repetition, the difficulty created by the spelling-out requirement appears. The opportunity to see the items repeatedly must eradicate the deleterious effect which the spelling-out requirement creates. In the experimental condition this opportunity does not exist.

But it was not clear whether spelling adversely affects the formation of associations or causes some difficulty in item learning. To gain some understanding of this problem, we decided to repeat the "spelling out" experiment and to "tap in" on the subjects, so to speak, during the learning process. Analysis, trial by trial, of the previous spelling-out experiment showed that control subjects learned almost four times as many items on the fourth trial as did the experimental subjects when tested by the usual aided recall method. By introducing a matching type of recognition test after the 4th trial, we sought to find out if the association was formed but not evoked by the aided recall method. The results of experiment 2 were clear. The 15 experimental subjects matched a total of 28 correctly, and the same number of control subjects matched 24 correctly. Thus, it is safe to conclude that no difference in number of correct associations existed between the groups, but that spelling seems to make the items less available for the experimental subjects. Once the items are made available as in the matching test, the correct associations are given equally well for both groups.

To check this conclusion experiment 3 was performed. Subjects were presented with single items, one at a time for 3 seconds each with a 5-second interval between them. Only one trial was given. Subjects in one group had to "spell" each item and subjects in the other group had to "pronounce" each item as it was presented. There were ten subjects in each condition. After a 1-minute rest, subjects were given a 2-minute free-recall period. Again the results were clear. The spelling group recalled a mean of 3.0 items (S.D., 1.8), whereas the pronouncing group recalled a mean of 5.5 (S.D., 1.7). A test of significance yielded a t of 3.20, which is significant since $p < .01$. The difference is accounted for primarily in the greater number of no-response errors by the spelling group, but these subjects also made many more errors in which the first letter only was correct than did those in the pronouncing group.

The spelling-out procedure makes it more difficult to learn items. The main question has been whether an association between two items develops instantaneously or gradually. For purposes of exploring this question it is not desirable to use the spelling-out procedure. Whatever accentuates the difficulty of learning items is not desirable. As to why spelling-out leads to difficulty one can only speculate that it leads to a fragmentation into parts of what in the pronouncing method is more of a unitary whole. Perhaps the trace is less available because it has a somewhat attentuated unity character.

IRVIN ROCK
GEORGE STEINFELD
Department of Experimental and Clinical Psychology, Yeshiva University, New York 19

References and Notes

1. I. Rock, *Am. J. Psychol.* **70**, 2 (19[illegible] I. Rock and W. Heimer, *Am. J. Psychol.* **72**, 1 (1959).
2. For example, L. L. Clark, T. G. Lansford, K. M. Dallenbach, *ibid.* **73**, 1 (1960); M. Wogan and R. H. Waters, *ibid.* **72**, 4 (1959).
3. For example, L. Postman, *ibid.* **75**, 3 (1962).
4. A. P. Chenzoff, paper read at Midwestern Psychological Association meeting, 1959.
5. G. R. Lockhead, *Am. J. Psychol.* **73**, 4 (1961).
6. A. B. Kristofferson, *Science* **134**, 2036 (1961).
7. Personal communications, 24 September 1962 and 4 March 1963 in which Kristofferson included details of the procedure and instructions to subjects. It was not clear from Kristofferson's article (*6*) that spelling was used in the test.
8. Postman (*3*) has recently raised the objection to the original procedure that the subject might not attend to some pairs if they are not required to respond during training.

11 March 1963

Membrane Permeability: Monolayer Relationships

Abstract. *A model of permeation of living membranes is proposed in which penetration by polar molecules takes place through islands composed of limited numbers of lipoidal molecules in a state comparable to that of certain compressed monolayers. These islands are visualized as scattered within a rigid, relatively impervious matrix. Relationships for penetration of monolayers by gases have been applied to this membrane model. Calculations on this basis demonstrate that the permeabilities relative to water are described at least as well by this model as by that assuming rigid pores of 4.25 Å radius.*

It has been postulated on theoretical grounds (*1*), and experimental evidence appears to be offered by modern electron microscopy (*2*), that the living membrane is a bimolecular leaflet of lipid, the aqueous surfaces of which are bounded by protein. The permeability characteristics of living membranes suggest that the lipoidal layers are the primary barriers to diffusion (*3*). Moreover, the penetrability of fatty monolayers is susceptible to change through alterations in the tightness of packing expressed as surface pressure (*4*); this result is of interest in view of the demonstration that the permeability changes in living membranes brought about by "stabilizing" (local anesthetics, alcohols, "inert gases") and "labilizing" (veratrum alkaloids) drugs are closely correlated with changes in monolayer packing induced by pharmacologically effective concentrations of these drugs (*5, 6*).

According to Archer and La Mer (*4*) and Barnes and La Mer (*7*), monolayer penetrability to water, p (the inverse of their monolayer resistance, r), may be expressed as an exponential function of the experimental activation energy, U; a frequency coefficient, C, can be lumped with energy and entropy terms which are assumed to undergo little change, thereby giving what is considered to be a constant C'. Therefore, if comparison is to be made of the penetrabilities of 2 different molecules, 1 and 2, one may write

$$p_1/p_2 = \exp{(U_2 - U_1)/RT} \qquad (1)$$

where R is the gas constant and T the temperature. Among the energy terms composing U, are U_M, in cal/mole, for the interaction of the individual methylene groups (CH_2) with each other, and the work of passage of a molecule of cross-sectional area, a, through a monolayer of surface pressure, S, in dy/cm; this work is Sa. Taking account of these specific terms, one may rewrite Eq. 1 as follows:

$$\ln \frac{p_1}{p_2} = n\,\frac{(U_{M2} - U_{M1})}{RT} + S\,\frac{(a_2 - a_1)}{kT} \qquad (2)$$

in which n is the number of CH_2 groups and k the Boltzmann constant. The U_M of monolayers is regarded as unaffected by a, hence the term containing it is ordinarily neglected in comparisons of monolayer penetration by different molecules (*8*).

The highest value of S obtainable for aliphatic molecules about 18 carbon atoms (25Å) long is of the order of 40 dy/cm. Even at this high surface pressure, Eq. 2 leads to permeabilities relative to water that are too large compared to experimental figures. Thus, if the radius of a molecule of H_2O is 1.5Å, and those of a molecule of methanol, ethylene glycol, and glycerol, respectively, are 1.83, 2.24, and 2.77Å (*9*), the relative permeabilities by computation are 0.71, 0.43, and 0.19, compared to the experimental values in the giant axon of squid of 0.65, 0.28, and 0.04 (*9*). The computations, as for the rigid-pore model calculations (*9*), ignore hydration energies.

Equation 2 can predict permeability better by considering the regions where permeation occurs as only a part of the surface of living membranes—in fact, islands composed of a limited number of lipoidal molecules in a relatively rigid, impervious matrix. Restricted regions have been proposed for ion penetration in excitable membranes (*10*). This concept also provides a basis for the fact that the ratio of the penetration rate of water in monolayers (*8*), to that in the squid giant axon membrane (*9, 11*), is approximately 1000 : 1. For simplicity, only one of the membrane lipid layers is regarded as governing permeation; attention has been called to several studies which suggest that this is the case for ions (*12*).

By limiting the number, m, of membrane molecules at the site of entry, and by fixing the area available to them, p is made more sensitive to the size of a penetrating molecule. This is because the passage of a molecule through an island decreases the area per membrane molecule by the factor a/m (a being the cross-sectional area of the penetrating molecule), which in turn will